Challenge 9 Strain Gages

Objective

In this lab, pairs of students will measure the strain in a cantilever beam under incrementally increasing static loads. Upon completion of this lab, students should be able to:

- Correctly use an electrical resistance strain gage in 1/4 bridge configuration
- Demonstrate wiring the B-102 beam with one longitudinal (upper surface) and one transverse aligned (lower surface) strain gage into the strain indicator and recorder unit
- Demonstrate wiring the B-104 beam, which has a rosette gage of three single gages oriented an angles to one another and also at an angle to the longitudinal axis of the beam
- As individuals, apply appropriate formulas along with the measured strain gage data to determine the following for a cantilever beam:
    - o the modulus of elasticity (E) for the beam's material, and o Poisson's ratio (v) of the beam's material.

Background

- Review the provided resources in the Challenges and Topics sections of the iLearn sites for class and lab o Lecture notes
    - o User Manual for P3
- Other resources, such on-line materials, or measurements texts from library, etc that YOU locate are certainly allowed, just be sure to cite them.

Challenge

Remember to document all your measurement processes for this guided set of activities. Your working notes should include your observations and calculations for: sources of uncertainties, consideration of significant figures and unit conversions, calculations and plots and then conclusions. Sketch(es) of setup and/or photos, as well as brand, model number, and serial number of equipment, are helpful for your working notes.

Note: You will have access to two types of instrumented beams, the B-102 or the B-103, first to obtain data, and then you will switch and use the other beam. You can complete all your measurements for one beam, then switch beams and go through the Activities 1, 2 and 3 again for the second beam. You are encouraged to complete Activities 1,2, and 3 as a pair of two students, then each of you conduct your own individual Activities 4 and 5 as well as individual writeups for Challenge 9.

Activity 1: Setup of beam

Determine the beam dimensions (either the B-102 or the B-103) using your choice of measuring instrument. Record the dimensions in your spreadsheet, with suggested format shown in Table 1. Note: The "moment arm length" is the free length of the beam, measured from the center of the strain gage location to the end of the beam where the static weight will be attached.

Clamp the beam to the edge of the lab table. Make sure to place the aluminum square between the c-clamp and the bottom edge of the tabletop. Failure to do so may damage the tabletop when the clamp is tightened.

Table 1 Beam Dimensions for B-102 and B-103

Beam Number	Beam Width, b (in)	Beam Thickness, h (in)	Moment Arm Length, L (in)
B-102			
B-103			

Activity 2: Strain Gage Connection

The wires attached to the strain gage are short, so these will need some sort of extension to reach the strain indicator and recorder box, P3. Suggestions include

- Using a flexure fixture that has longer wires as a “pigtail” bundle. You can connect the gage wires needed into the knobs on the side of the fixture, then connect the correspondingly numbered wires from the pigtail to the P3 connections. NOTE: This flexure fixture is used for providing known deflections to a beam, however we are not using that feature.
- Use a breadboard to provide a wiring junction, with extension wires going to the P3
- Use alligator clips and wires as needed, this is likely the most fragile and noise prone setup.

Connect the **three (3)** gage wires to the P3 Strain Indicator and Recorder using a quarter-bridge arrangement.

- HINT: Unsure what the quarter-bridge configuration is? Review the background material and/or the equipment manual and/or find videos on-line, consult the image at the end of this guide, and if all else fails check with your TA. Document your troubleshooting process in your working notes. There is a helpful diagram on the underside of the P3 cover.

Follow the steps in the P3 User Manual and/or the video provided to now check the connection of the strain gage and to prepare the circuit for taking measurements.

- Steps to prepare the circuitry include selecting the ¼ bridge configuration, entering the gage factor for the strain gage attached, and zero balancing the channel.

Note:

- For the B-102 beam, you will have two gages to connect and conduct loading for one at a time. One gage on one channel as ¼ bridge. Since the one of the tabs for the transverse gage are connected to the one of the tabs for the axial gage, you will only be able to connect one gage at a time. This means you will be repeating Activity 2 and 3 for the transverse gage.
- For the B-103 beam, you will have three gages to connect and conduct loading for one at a time. One gage, for example “a”, connected at a time, then loading, then connecting the next gage, and loading again, repeating Activity 2 and 3 until all three gages have been read.

Activity 3: Loading the Beam

Deflect the cantilever beam in six increments by successively adding “known” masses, converted to weight. Use the 1000-gram mass sets with hangar. When using the hangar, please be CAREFUL that you do not drop the masses, that will damage their integrity and the marked mass amount could become inaccurate.

- You might choose to verify these masses, as they are mass produced, and have not been calibrated.
- Use a minimum of six incrementally increasing loads of 0, 200, 400, 600, 800, and 1000 g. You may choose to exceed the minimum number of increments.
- You will need to convert the known mass values into known weights, be careful and consistent with your units!

Record the strains indicated for each load level in your spreadsheet. A suggested format is shown in Table 2. Note the two right hand columns will represent calculated values. It will be important to apply your loads in the same fashion for each new time you conduct the loading activity.

Table 2 – Strain Gage Readings for the B-102

Increments of Mass applied	**Total Weight, F (lbf)**	**Axial Gage Strain Reading, ε_a (μ strain)**	**Transverse Gage Strain Reading, ε_t (μ strain)**		**Bending Stress, s (psi) calculated**	**Poisson’s Ratio, (v) calculated**

Note: If you are using the beam B-102 first, then you will be filling out rows of data for Table 2. And if you are using the beam B-103 first, then you will be filling out rows of data for Table 3 first. Then once you have access to the other beam, you can fill out the other table.

Table 3 – Strain Gage Readings for B-103

Increments of Mass applied	**Total Weight, F (lbf)**	**(a) Gage Strain Reading, ε_a (μ strain)**	**(b) Gage Strain Reading, ε_b (μ strain)**	**(c) Gage Strain Reading, ε_c (μ strain)**		**Bending Stress (psi)** calculated	**Principal Strain ε_1 (μ strain)** calculated	**Principal Strain ε_2 (μ strain)** calculated	**Poisson's Ratio, v** calculated

Activity 4: Calculations and Plot for Beam B-102

- Using data from Table 2, compute the Bending Stress for the beam with the known loads applied using the formulas provided in Table 4.
- Create a plot of the stress-strain data. Bending Stress, column 4, should be in units of (psi) on the vertical axis and the axial strain, column 2, should be in μ strain on the horizontal axis.
- Perform a linear least-squares fit on the plotted data to **Determine the modulus of elasticity**. Remember, the modulus of elasticity is the ratio of stress vs. strain, ie the slope of the line fit. Don't forget units!

> Reality check: You likely have a good idea of what this material is and what value you should obtain for modulus of elasticity E.
> If you have not memorized values of E for steel and aluminum, now is a good time to do so!

- Determine the Poisson's ratio for each measured strain set, that is for each load amount, you have a axial and transverse strain, and you can make that into a ratio. Then compute the average value of the Poisson's ratio.

Activity 5: Calculations and Plot for Beam B-103

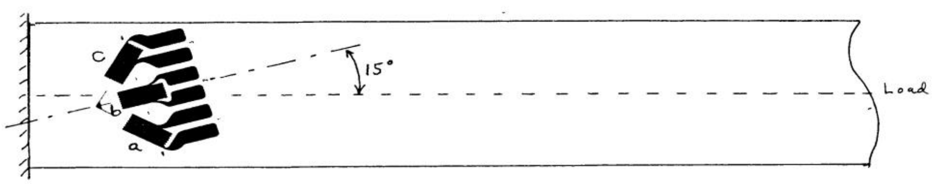
- Using data from Table 3, compute the Bending Stress for the beam with the known loads applied using the formulas provided in Table 4.
- Compute the principle strains ε_1 and ε_2, obtained from the a, b, and c rosette gages.
    - Note: the maximum principal strain, ε_1 , is the axial or longitudinal strain and the minimum principal strain, ε_2 , is the transverse strain.
- Create a plot of the stress-strain data. Bending stress (Column 6) should be in units of psi on the vertical axis and axial strain (maximum principal strain ε_1 in Column 7) should be in μ strain on the horizontal axis.
- Perform a linear least-squares fit on the plotted data to Determine the modulus of elasticity, watching for units.
- Determine the Poisson's ratio for each measured strain set. In other words, for each load amount, you have an axial strain in the longitudinal direction (ε_1) and transverse strain (ε_2), and you can ratio these to find Poisson's ratio. Having found that ratio for each load amount, then compute the average value of the Poisson's ratio.

Conclusions

Record your final comments and observations regarding the outcomes of this lab, detailing what have you leaned from the two different types of instrumented beams, B-102 (axial and transverse) and B-103 (rosette).

Useful formulas for this Challenge have been pulled together from various sources to create Table 4.

Table 4 – Provided Formulas

Bending Stress on Beam Surface	σ= M c / I
Bending Moment	M = F L
Distance from neutral axis	c = h / 2, distance from the neutral axis to the beam surface
Unit Conversion	1 lbm = 454 g (Note: A mass of 1 lbm has a weight of 1 lbf under standard earth gravity)
Area Moment of Inertia	I = (b h^3) / 12 (rectangular cross-section) Where b is the base width and h is the thickness or height of the beam crosssection
Poisson's Ratio	v = - $\varepsilon_t / \varepsilon_a$ Where "t" represents "transverse" and "a" represents "axial"
Calculations for Principal Strains from Rosette Gage (three gages at 45deg)	 **Principal Strains:** $\epsilon_1 = \frac{\epsilon_a + \epsilon_c}{2} + \frac{1}{\sqrt{2}}\sqrt{(\epsilon_a - \epsilon_b)^2 + (\epsilon_b - \epsilon_c)^2}$ $\epsilon_2 = \frac{\epsilon_a + \epsilon_c}{2} - \frac{1}{\sqrt{2}}\sqrt{(\epsilon_a - \epsilon_b)^2 + (\epsilon_b - \epsilon_c)^2}$

A possible Reference for "linear least squares":
- https://www.itl.nist.gov/div898/handbook/pmd/section1/pmd141.htm
- You may use any reference you choose for detailing the steps of the linear least squares process, just be sure to include the source in your working notes.